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REVIEW ARTICLE

Applications of Nanotechnology – Review

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ABSTRACT: Nanotechnology has a great influence on modern technology. Future applications will focus on shelf life, food quality, safety, fortification and biosensors for contaminated or spoiled food, irrigating water and drinking water. Among the various nanotechnologies, nano-analysis is most commonly seen in forensic science with instrumentations including transmission electron microscope (TEM), scanning electron microscope (SEM), atomic force microscope (AFM) and Raman micro spectroscopy (Micro-Raman). Due to their small size and unique physicochemical characteristics, nanomaterials have gained importance in the agri-food sector, notably in preservation and packaging. Novel nanocarriers like liposomes, niosomes, nanoemulsions, microemulsion, solid lipid nanoparticles, nanostructured lipid carrier, and nanospheres have replaced the usage of conventional delivery system. These novel nanocarriers have advantages of enhanced skin penetration, controlled and sustained drug release, higher stability, site specific targeting, and high entrapment efficiency. Nanotechnology is applicable in various fields of dental sciences such as orthodontic, Nano-sized materials have been applied in various fields of dentistry. Nanotechnology can be employed in orthodontics to enhance the quality of treatment. This review presents resent aspects of "Nanotechnology" in different areas of science. It gives a brief description about Nanotechnology and its application in various fields' viz. wastewater treatment, Forensic, agriculture, Applications of Nanotechnology in Cosmeceuticals, in Orthodontics and in oil & gas recovery will be discussed.

KEYWORDS: Nanotechnology Water treatment; Forensic science; Agriculture; Nanocosmeceuticals; Orthodontics; Oil recovery.

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INTRODUCTION

Nanotechnology has been applied successfully in many applications including nanoelectronics, nanobiomedicine, and nanodevices. Nanotechnology is the advancement by the use of techniques to study physical phenomena and construct structures in the physical size range of 1–100 nm, as well as by adding of these structures into applications. However, the introduction of high speed with high storage capacity computers, as well as accurate instruments for measuring and by manipulating at nanoscale, have accelerated the development of nanoscale structures and devices into reality. Nanotechnology is making valuable improvements on various scientific fields in science and technology today. Widely, it is determined as the study, design, synthesis, manipulation, application of functional materials, devices, creation, and systems through control of matter at the nanometer scale. It has been applied to many areas of study including electronic engineering, physical sciences, materials sciences, biomedical sciences and many others.

Nanotechnology was determined in the science and engineering technology in the characterization, design, synthesis, and application of materials and devices in at least one dimension is on the nanometer scale of 1–100 nm.

Applications of Nanotechnology in daily life is mostly used on small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering, food packing, nano fabrics, nano sized environmental sensors and nano sized environmental treatment, corrosion resistant ceramics, water purification and in vitro diagnostics in healthcare.

Here, we provide an overview of applications of nanotechnologies for water and wastewater treatment, Forensic science; Agriculture; Nanocosmeceuticals; Orthodontics; Oil recovery. The major applications of nano materials in various fields are critically reviewed based on their functions in unit operation processes.

Applications for water and wastewater treatment

Water is the most essential substance for all life on earth and a precious resource for human civilization.

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Reliable access to clean and affordable water is considered one of the most basic humanitarian goals, and remains a major global challenge for the 21st century.

Our current water supply faces enormous challenges, both old and new. Worldwide, some 780 million people still lack access to improved drinking water sources [1]. It is urgent to implement basic water treatment in the affected areas (mainly in developing countries) where water and wastewater infrastructure are often non-existent. In both developing and industrialized countries, human activities play an ever-greater role in exacerbating water scarcity by contaminating natural water sources. The increasingly stringent water quality standards, compounded by emerging contaminants, have brought new scrutiny to the existing water treatment and distribution systems widely established in developed countries. The rapidly growing global population and the improvement of living standard continuously drive up the demand. Moreover, global climate change accentuates the already uneven distribution of fresh water, destabilizing the supply. Growing pressure on water supplies makes using unconventional water sources (e.g., storm water, contaminated fresh water, brackish water, wastewater and seawater) a new norm, especially in historically water-stressed regions. Furthermore, current water and wastewater treatment technologies and infrastructure are reaching their limit for providing adequate water quality to meet human and environmental needs.

Recent advances in nanotechnology offer leapfrogging opportunities to develop next-generation water supply systems. Our current water treatment, distribution, and discharge practices, which heavily rely on conveyance and centralized systems, are no longer sustainable. The highly efficient, modular, and multifunctional processes enabled by nanotechnology are envisaged to provide high performance, affordable water and wastewater treatment solutions that less relies on large infrastructures [2]. Nanotechnology-enabled water and wastewater treatment promises to not only overcome major challenges faced by existing treatment technologies, but also to provide new treatment capabilities that could allow economic utilization of unconventional water sources to expand the water supply.

Carbon based Nano-adsorbents

Organic removal

Carbon Nano Tubes (CNTs) have shown higher efficiency than activated carbon on adsorption of various organic chemicals [3]. Its high adsorption capacity mainly stems from the large specific surface area and the diverse contaminant CNT interactions. The available surface area for adsorption on individual CNTs is their external surfaces [4]. In the aqueous phase, CNTs form loose bundles/aggregates due to the hydrophobicity of their graphitic surface, reducing the effective surface area. On the other hand, CNT aggregates contain interstitial spaces and grooves, which are high adsorption energy sites for organic molecules [6]. Although activated carbon possesses comparable measured specific surface area as CNT bundles, it contains a significant number of micropores inaccessible to bulky organic molecules such as many antibiotics and pharmaceuticals [7]. Thus CNTs have much higher adsorption capacity for some bulky organic molecules because of their larger pores in bundles and more accessible sorption sites. A major drawback of activated carbon is its low adsorption affinity for low molecular weight polar organic compounds. CNTs strongly adsorb many of these polar organic compounds due to the diverse contaminant CNT interactions including hydrophobic effect, pep interactions, hydrogen bonding, covalent bonding, and electrostatic interactions [4] The p electron rich CNT surface allows pep interactions with organic molecules with C]C bonds or benzene rings, such as polycyclic aromatic hydrocarbons (PAHs) and polar aromatic compounds [5,8]. Organic compounds which have eCOOH, eOH, eNH2 functional groups could also form hydrogen bond with the graphitic CNT surface which donates electrons [4]. Electrostatic attraction facilitates the adsorption of positively charged organic chemicals such as some antibiotics at suitable pH [7].

Carbon nanotubes are one of the allotropes of carbon and these can be considered as various structural forms of carbon element. Basically CNTs are composed of cylindrical shape rolled up in a tube like structure. CNTs are of two types, single walled carbon nanotubes (SWCNTs) and multiwalled carbon nanotubes (MWCNTs), where single walled carbon nanotubes are composed of single graphene sheet with a roll up and multiwalled carbon nanotubes are of multiple graphene roll up sheets. Fig. 1 shows the structures of SWCNTs and MWCNTs.

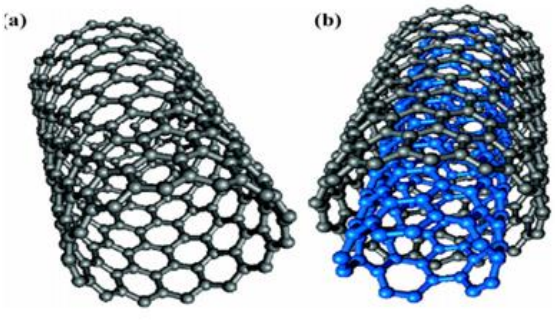

Fig.1. Structure representations of (a) SWCNTs and (b) MWCNTs

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CNTs, with their high surface-active site to volume ratio and controlled pore size distribution, have an exceptional sorption capability and high sorption efficiency compared to conventional granular and powder activated carbon, which have intrinsic limitations like surface active sites and the activation energy of sorption.

There is no doubt that CNTs possess great potential as superior adsorbents for removing divalent metal ions, dyes, NOMs and THMs from aqueous solution, but their relatively high unit cost restricts their practical use. In addition to it, raw CNTs may possess some degree of toxicity due to the presence of metal catalysts while chemically functionalized CNTs have not demonstrated any toxicity so far [9]. As a result, the practical use of CNTs as sorbents in water and wastewater treatment depends on the continuation of research into the development of a cost effective way of CNTs production and the no or low toxicity of CNTs and CNT related materials such as carbon nanocrystals (CNCs).

Even through carbon nanotubes have many significant advantages, but their use on an industrial scale for practical applications is not expected in the midterm because of their high production costs [10]. Point-of-use applications that require small quantities of CNTs are more competitive; for example, for the elimination of heavily degradable contaminants such as many antibiotics and pharmaceuticals [11-13]. Therefore, more research is needed to come up with the practical and economical solutions for using CNTs in water treatment.

Potential application in water treatment

Nano-adsorbents can be readily integrated into existing treatment processes in slurry reactors or adsorbers. Applied in the powder form, nano-adsorbents in slurry reactors can be highly efficient since all surfaces of the adsorbents are utilized and the mixing greatly facilitates the mass transfer. However, an additional separation unit is required to recover the nanoparticles. Nano-adsorbents can also be used in fixed or fluidized adsorbers in the form of pellets/beads or porous granules loaded with nano-adsorbents. Fixed-bed reactors are usually associated with mass transfer limitations and head loss; but it doesn't need future separation process. Applications of nano-adsorbents for arsenic removal have been commercialized, and their performance and cost have been compared to other commercial adsorbents in pilot tests [14]. ArsenXnp is a commercial hybrid ion exchange medium comprising of iron oxide nanoparticles and polymers. ADSORBSIA is a nanocrystalline titanium dioxide medium in the form of beads from 0.25 to 1.2 mm in diameter. Both nano-adsorbents were highly efficient in removing arsenic and ArsenXnp required little backwash [14,15]. The estimated treatment cost for ArsenXnp is \$0.25w\$0.35/1000 gal if the medium is regenerated, similar to \$0.37/1000 gal of Bayoxide E33, a high performance granular iron oxide adsorbent [14,16]. ArsenXnp and ADSORBSIA have been employed in small to medium scale drinking water treatment systems and were proven to be cost-competitive.

Photo catalysis

The overall efficiency of a photocatalytic water treatment process strongly depends on the configuration and operation parameters of the photo-reactor. Two configurations are commonly used: slurry reactors and reactors using immobilized TiO2. Various dispersion/recovery or catalyst immobilization techniques are being pursued to maximize its efficiency. Extensive investigation on operating parameters has been carried out with these lab or pilot scale systems. A recent critical review outlines the effects of water quality and a wide range of operating parameters including TiO_2 loading, pH, temperature, dissolved oxygen, contaminant type and concentration, light wavelength and intensity. Readers are referred to this review for details regarding process optimization. A commercial product, Purifics Photo-Cat system, has treatment capacity as high as 2 million gallon per day with a small footprint of 678 ft2 . Pilot tests showed that the Photo-Cat system is highly efficient for removing organics without producing waste streams and it operates with relatively low specific power consumption of about 4 kWh/m3 [17, 18, 19]. Nano-TiO2 facilitated solar disinfection (SODIS) has been extensively tested and appears to be a feasible option to produce safe drinking water in remote areas of developing countries. The SODIS system can be small scale for one person or scaled up to medium size solar compound parabolic collectors.

Disinfection and microbial control

Antimicrobial nanomaterials are envisaged to find their applications in three critical challenges in water/wastewater systems: disinfection, membrane biofouling control, and biofilm control on other relevant surfaces. Nano-Ag has good potential for application in POU treatment. It can improve water quality for high-end use, or provide another barrier against waterborne pathogens for vulnerable population. Commercial devices utilizing nano-Ag are already available, e.g., MARATHON and Aquapure systems. Nano-Ag has also been incorporated into ceramic microfilters as a barrier for pathogens, which can be employed in remote areas in developing countries [20]. The antimicrobial properties, fibrous shape, and high conductivity of CNTs enable novel CNT filters for both bacteria and virus removal: The thin layer of CNTs effectively remove bacteria by size exclusion and viruses by depth filtration (Brady-Estevez et al., 2010); the retained bacteria are largely inactivated by CNTs within hours. With a small intermittent voltage (2e3 V), MWNTs can directly oxidize attached bacteria and viruses and lead to inactivation in seconds [21, 22]. The applied electric potential also enhances viral transport to the anodic CNTs [21]. Such CNT filters can be used as high performance POU devices for water disinfection with minimal to no power requirement.

Applications to Forensic Science

Nanotechnology is making valuable contributions to various scientific fields in science and technology today. Recently, many new nanoscale sample analysis techniques in genetic, medicine, analytical chemistry have been applied to fields of forensic sciences. [23] Nanotechnology contributes to forensic sciences in two ways. Since it can detect and analyze samples in the nanoscale, critical evidence that could not be collected and analyzed before due to the detection limits of the instruments can now be analyzed and used to support the investigations. In addition, namomaterials possess novel properties that can assist the collection and detection of evidence which cannot be acquired previously. Some examples include trace amounts of gunshot residues, heavy metals, explosives, DNA on fingerprint or palm prints, and so on. Foreign law enforcement agencies have already begun to consider sponsoring more research projects on the forensic applications of nanotechnology. According to the National Nanotechnology Initiative (www.nano.gov) fiscal year 2006 budget request, the National Institute of Justice (NIJ) of United State Department of Justice (USDOJ) has two separate project areas that incorporate nanotechnology – DNA Research and Development ($1.0 million) and Chemical and Biological Defense ($1.0 million). The DNA Research and Development program consists of fundamental research and the demonstration of chip-based or micro-device technologies to analyze DNA in forensic applications. The Chemical and Biological Defense program is focuses on developing a wearable, low-cost device to provide warning of exposure to unanticipated chemical and biological hazards in sufficient time for its wearer to take effective protective measures.

Nanotechnology is making valuable contributions to various scientific fields in science and technology today. Generally, it is defined as the study, design, creation, synthesis, manipulation, application of functional materials, devices, and systems through control of matter at the nanometer scale. It has been applied to many areas of study including electronic engineering, physical sciences, materials sciences, biomedical sciences and many others.

Applications to Agriculture

Agricultural products influence most aspects of life, including everyday materials, such as fuels, textiles, furniture, feedstock for biobased products including food and feed. Technology advancement is needed to achieve the future global needs from agriculture. Nanoscience and nanotechnology have shown great potential in improving food safety, quality, product traceability, nutrient delivery, enhancing packaging performance, and improving agricultural and food processing. Figure2 represents the major applications of nanotechnology in food processing and packaging, and the same has already been discussed in many review articles earlier.

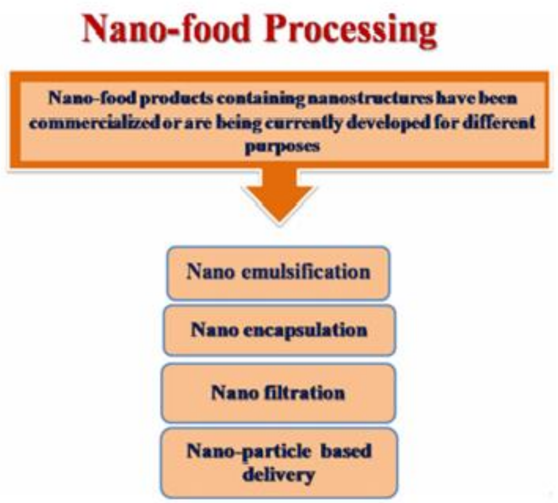
Nano-food Processing
Nano-food products containing nanostructures have been commercialized or are being currently developed for different purposes
Nano emulsification
Nano encapsulation
Nano filtration
Nano-particle based delivery

Fig. 2. Major types of nanostructures or processes which are being used to develop nanofoods to be launched in market

Nanomaterials are also applicable in the agriculture such as nanoscale carriers, fabricated xylem vessels, nanolignocellulosic materials, clay nanotubes, photocatalysis, bioremediation of resistant pesticides, disinfectants, agricultural wastewater treatment, nanobarcode technology, quantum dots for staining bacteria, and different types of nanobiosensors.

Applications to Cosmeceuticals

Cosmetics can be defined as the products which amplify the appearance of the skin, intensify the cleansing, and promote the beauty of the skin [24]. As reported, the use of cosmetics was attributed to Egyptians around 4000BC and later Greeks, Romans, Chinese, Japanese, and Americans started using cosmetics. In the late 19th century, the use of cosmetics was secretly done by the women with household items in western countries and by 20th century the cosmetics were being done without concealment. By the 21th century, the cosmetics are being enormously used and with the development in technology, innovative cosmetic formulations are being developed by the incorporation of the latest technologies [25, 26].There are a number of advantages of nano Cosmeceuticals. Namely, they provide the controlled release of active substances by controlling the drug release from carriers by several factors including physical or chemical interaction among the components, composition of drug, polymer and additives, ratio, and preparation method. They are used in hair care preparations, such as in treatment of hair loss and to prevent hair from turning grey such as Identik Masque Floral Repair, Origem hair recycling shampoo, and Nirvel hair-loss control shampoo. Nanocosmeceuticals make the fragrances last longer, for example, Allure Parfum and Allure Eau Parfum spray by Chanel. These make the skin care formulations more effective and increase the efficacy of sunscreens by improving UV protection in them. By having very small size of the particles, the surface area is increased which allows the active transport of the active ingredients into the skin. Occlusion provides the enhancement in the penetration and skin hydration is increased. Cosmeceuticals have high entrapment efficiency and good sensorial properties and are more stable than the conventional cosmetics. Most of the nanoparticles are suitable for both lipophilic and hydrophilic drug delivery. Nanomaterials are widely used in the preparation of anti wrinkle creams, moisturizing creams, skin whitening creams, hair repairing shampoos, conditioners, and hair serums. Several positive aspects of nanocosmeceuticals are discussed in Figure 3[27].

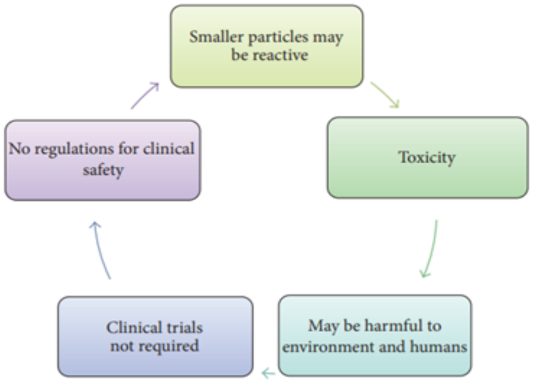
Smaller particles may be reactive
Toxicity
May be harmful to environment and humans
Clinical trials not required
No regulations for clinical safety

Fig. 3.Pictorial presentation of negative aspects of nanocosmeceuticals

Applications of Nanotechnology in Orthodontics

Nanotechnology has wide usage for various medical purposes such as drug delivery, eliminating microorganisms and etc [28-30]. For instance, using nano-based antimicrobial agents can efficiently disinfect root canal of tooth. Employing nanomaterials in devices makes it possible to enhance the mechanical strength and efficiency of the systems [31,32]. Several researches have been carried out on the applications of nanotechnology in different tools and mediums to achieve more efficient and reliable performance [33-35].

Nanotechnology is applicable in various fields of dental sciences such as orthodontic, endodontic and restorative dentistry [36,37]. Danelon et al [38] added sodium trimetaphosphate nanostructures to a fluoride toothpaste and analyzed its remineralization influence. It was mentioned that nanotechnology can be used as antimicrobial for root canal irrigation, as photo sensitizer in photodynamic therapy.

Applications of Nano materials in concrete

Nano concrete is a concrete that utilizes nano materials or a concrete with nano materials added in which the size of the nano particles is less than 500 nm [39-45]. It was believed that the addition of nano particles in concrete improve the strength of conventional concrete. Nano particle works in concrete by improving the bulk properties or also known as packing model structure. Ultra or nano particles can perform a superb filler effect by refining the intersectional zone in cement and producing more density concrete. By acting as good filler, their manipulation or alteration in the cement matrix system occurs to provide a new nanoscale structure. Common discrepancies in concrete microstructure such as micro void, porosity and deterioration due to alkali silica reaction will be eliminated. Next, nano materials start to evolve when they become new binding agent which is smaller than cement particles. This improves the structure of hydration gel providing a neat and solid hydration structure. In addition, through the combination of filler and additional chemical reaction in hydration system, a new concrete called nano concrete with durable and enhanced performance has been developed [46-48].

Implementation of nano technology in concrete has started since the early millennium in line with the increasing demand for UHPC. Conventional mix formulations of UHPC with the inclusion of silica fumes provide better durability and strength. However, due to limited availability and also the high cost of silica fume makes UHPC technology declining and less demanding compared to HSC. Since then, emerging technology in nano production has developed an alternative to silica fume. By applying nano production concept, a common nano material which mimics the action of silica fume is designed. Nano silica is one of the newest technologies in nano process which has been used as an alternative to silica fume [49]. Since the breakthrough of nano silica, many nano based particles has been developed to be used in concrete. Nano alumina [50], titanium oxide [51], carbon nano tube [52] and polycarboxylates [53] are examples of nano materials used in nano concrete. The following sub-section explains on the production and application of nano materials.

Applications of Nanotechnology in Oil and Gas Industry

The emergence of nanotechnology as a force in multidisciplinary research has led to the development of nanomaterials, where the oil and gas industry can adopt the principles of nanotechnology to solve practical problems encountered in oilfield development, especially in improving recovery efficiency of the oilfield. A growing trend in adopting nanotechnology in oil and gas industry is evident over the past 5 years. Several studies and reviews have documented the theory to practice in enhanced oil recovery where nanotechnology has been applied [54,55]. The impact of nanochemistry, including the use of polymer-coated nanoparticles, on the processes and mechanisms of enhanced oil recovery (EOR) has been examined. Oil companies are devoting increasing resources to nanotechnology research and development, both in-house research and development facilities and in partnership with universities. In 2008, the Advanced Energy Consortium (AEC) was jointly launched by Schlumberger, TOTAL, Shell, BP, etc., with the goal of collaborating with research institutes to develop and apply nanotechnology in the oil and gas industry. ExxonMobil, Chevron, and Halliburton are also active in nanotechnology exploration at the laboratory level and in oilfield application tests [56,57].

Drilling and Completion

Nanomaterials play a multifunctional role in the drilling and completion process, especially in complex formations and extreme environments, such as high-temperature deep wells. There exist several advantages by adding nanomaterials into drilling and completion fluids. [58,59]

Stabilizing wellbore; Nanoparticles can form a compact filter cake on the wellbore, which can avoid or reduce the phenomena of water swelling and wellbore collapse.

Reducing filter loss; By introducing absorbing polymers in drilling fluid, nanoparticles can seal off nano/micro-sized pores on the wellbore, reducing the loss of drilling fluid.

Improving rheology; Nanoparticles can increase the apparent viscosity and dynamic shearing force of the drilling system, thereby improving rheological properties.

Increasing thermal stability; Drilling and completion fluids that contain nonmaterial’s may possess higher temperature tolerance, and can be applied in drilling deep wells.

CONCLUSION

Nanotechnology is considered to be the most promising and revolutionizing field. Nanotechnology for water and wastewater treatment is gaining momentum globally. The unique properties of nanomaterials and their convergence with current treatment technologies present great opportunities to revolutionize water and wastewater treatment. Most of the known forensic applications of nanotechnology focus on the development and improvement of DNA microchips and array. The understanding of the safe application of nanoscience and nanotechnology in agri-food and water quality management will help in the sustainable growth of ‘nano agri-technology’.

Nano products should be fabricated in such a way that their value and health of the customers are improved. Clinical trials are not required for the approval of cosmeceuticals so the manufacturers enjoy the benefit of avoid the holding clinical trials and lengthy procedures. Strict laws should be implemented on the regulation and safety of cosmeceuticals and nanoparticles used in them. Some of the types of nano particles such as silver are applicable as antimicrobial agents. Utilizing the nano particles in orthodontics materials can reduce the survival of microorganisms.

From the review of the existing literature, it is clear that the use of nano materials in concrete is beneficial in improving some technical properties of cement based materials although it deficient in some properties for example on water demands. In this review also, utilization of nano materials in concrete is reported. Nano silica, alumina and titanium oxide are among the nano materials used in the current research in developing the nano based concrete. In conclusion, nanotechnology has the potential to change the technology landscape of the oil and gas industry.

REFERENCES

[1] WHO, 2012. Progress on Drinking Water and Sanitation. https://www.who.int/water_sanitation_health/publications/jmp_report-2012/en/

[2] Qu X L, Brame J, Li Q, Alvarez JJP, 2013. Nanotechnology for a safe and sustainable water supply: enabling integrated water treatment and reuse, Accounts of Chemical Research, 46 (3), 834-843.

[3] Pan B, Xing BS, 2008. Adsorption mechanisms of organic chemicals on carbon nanotubes, Environmental Science and Technology, 42 (24), 9005-9013.

[4] Yang K, Xing B S, 2010. Adsorption of organic compounds by carbon nanomaterials in aqueous phase: Polanyi theory and its application, Chemical Reviews, 110 (10), 5989-6008.

[5] Chen W, Duan L, Zhu DQ, 2007. Adsorption of polar and non polar organic chemicals to carbon nanotubes, Environmental Science and Technology, 41 (24), 8295-8300.

[6] Pan B, Xing B, 2008.Adsorption mechanisms of organic chemicals on carbon nanotubes, Environ. Sci. Technol, 42, 9005–9013.

[7] Ji LL, Chen W, Duan L, Zhu DQ, 2009. Mechanisms for strong adsorption of tetracycline to carbon nanotubes: a comparative study using activated carbon and graphite as adsorbents, Environmental Science and Technology, 43 (7), 2322-2327.

[8] Lin DH, Xing BS, 2008. Adsorption of phenolic compounds by carbon nanotubes: role of aromaticity and substitution of hydroxyl groups, Environmental Science and Technology, 42 (19), 7254-7259.

[9] Chen C, Wang X, 2006. Adsorption of Ni(II) from aqueous solution using oxidized multiwall carbon nanotubes, Ind. Eng. Chem. Res, 45, 9144–9149.

[10] De Volder MFL, Tawfick SH, Baughman RH, HartAJ, 2013.Carbon nanotubes: present and future commercial applications, Science, 339, 535–539.

[11] Ji L, Chen W, Duan L, Zhu D, 2009. Mechanisms for strong adsorption of tetracycline to carbon nanotubes: a comparative study using activated carbon and graphite as adsorbents, Environ. Sci. Technol, 43, 2322– 2327.

[12] Cong Q, Yuan X, Qu J, 2013. A review on the removal of antibiotics by carbon nanotubes, Water Sci. Technol, 68, 1679–1687.

[13] Qu X, Alvarez PJ, Li Q, 2013. Applications of nanotechnology in water and wastewater treatment, Water Res, 47, 3931–3946.

[14] Aragon M, Kottenstette R, Dwyer B, Aragon A, Everett R, Holub W, Siegel M, Wright J, 2007. Arsenic Pilot Plant Operation and Results, Sandia National Laboratories, Anthony, New Mexico.

[15] Sylvester P, Westerhoff P, Mooller T, Badruzzaman M, Boyd O, 2007. A hybrid sorbent utilizing nanoparticles of hydrous iron oxide for arsenic removal from drinking water, Environmental Engineering Science, 24 (1), 104-112.

[16] Westerhoff P, De Haan M, Martindale A, Badruzzaman M, 2006. Arsenic adsorptive media technology selection strategies, Water Quality Research Journal of Canada, 41 (2), 171-184.

[17] Al-Bastaki NM, 2004. Performance of advanced methods for treatment of wastewater: UV/TiO2, RO and UF, Chemical Engineering and Processing, 43 (7), 935-940.

[18] Benotti M.J, Stanford BD, Wert EC, Snyder SA, 2009. Evaluation of a photocatalytic reactor mem brane pilot system for the removal of pharmaceuticals and endocrine disrupting compounds from water, Water Research, 43 (6), 1513-1522.

[19] Westerhoff P, De Haan M, Martindale A, Badruzzaman M, 2006. Arsenic adsorptive media technology selection strategies, Water Quality Research Journal of Canada, 41 (2), 171-184.

[20] Peter-Varbanets M, Zurbrugg C, Swartz C, Pronk W, 2009. Decentralized systems for potable water and the potential of membrane technology, Water Research, 43 (2), 245-265.

[21] Rahaman MS, Vecitis CD, Elimelech M, 2012. Electrochemical carbon-nanotube filter performance toward virus removal and inactivation in the presence of natural organic matter, Environmental Science and Technology, 46 (3), 1556-1564.

[22] Vecitis CD, Schnoor MH, Rahaman MS, Schiffman JD, Elimelech M, 2011. Electrochemical multiwalled carbon nanotube filter for viral and bacterial removal and inactivation, Environmental Science and Technology, 45 (8), 3672-3679.

[23] Brettell TA, Butler JM, Saferstein R, 2005.Forensic science, Anal. Chem, 77(12), 3839-3860.

[24] Gautam A, Singh R, Vijayaraghavan, 2011. Dermal exposure of nanoparticles: an understanding, Journal of Cell and Tissue Research, 11 (1), 2703–2708.

[25] Sathiyapriya,R., Hariharan, V., Prabakaran, K., Durairaj, M., Aroulmoji, V. 2019. Nanotechnology in Materials and Medical Sciences, Int. J. Adv. Sci. Eng. 5(3) 1077-1084.

[26] Dureja H, Kaushik D, Gupta M, Kumar V, Lather V, 2005. Cosmeceuticals: an emerging concept, Indian Journal of Pharmacology, 37 (3), 155–159.

[27] Antonio JR, Antonio CR, Soares-Cardeal IL, Ballavenuto JMA, Oliveira JR, 2014. Nanotechnology in dermatology, Anais Brasileiros de Dermatologia, 89(1), 126– 136.

[28] Karimi-Maleh H, Fallah Shojaei A, Karimi F, Tabatabaeian K, 2018. Au Nanoparticle Loaded with 6-Thioguanine Anticancer Drug as a New Strategy for Drug Delivery, J Nanostructures.

[29] Fathollahipour S, Ghaee A, AboueiMehrizi A, Koosha M, 2016. Controlled Antibiotic Delivery by Gelatin Nanospheres: Optimization,

Characterization and Antibacterial Evaluation, J Nanostructures, 6(4), 285–292.

[30] Mohamadian F, Eftekhar L, Haghighi Bardineh Y, 2018. Applying GMDH artificial neural network to predict dynamic viscosity of an antimicrobial nanofluid, Nanomedicine j, 5(4), 217–221.

[31] Esmaeili J, Mohammad jafari AR, 2018. Increasing flexural strength and toughness of cement mortar using multi-walled Carbon nanotubes, Int J Nano Dimens, 5(0), 399–407.

[32] Parvaneh V, Shariati M, Nezakati A, 2015. Statistical analysis of the parameters influencing the mechanical properties of layered MWCNTs/PVC nanocomposites, Int J Nano Dimens, 6(5), 509–516.

[33] AlhuyiNazari M, Ahmadi MH, Ghasempour R, Shafii MB, 2018. How to improve the thermal performance of pulsating heat pipes: A review on working fluid, Renew Sustain Energy Rev, 91, 630–638.

[34] Ahmadi MH, Mirlohi A, Nazari MA, Ghasempour R, 2018. A review of thermal conductivity of various nanofluids, J Mol Liq. 265(1)181-188.

[35] Nazari MA, Ghasempour R, Ahmadi MH, Heydarian G, Shafii MB, 2018. Experimental investigation of graphene oxide nanofluid on heat transfer enhancement of pulsating heat pipe, IntCommun Heat Mass Transf, 91, 90–94.

[36] Sharan J, Singh S, Lale S V, Mishra M, Koul V, Kharbanda OP, 2017. Applications of Nanomaterials in Dental Science: A Review, J NanosciNanotechnol, 17(4), 2235–2255.

[37] Hamid Reza Ghorbani, 2017. The study of anticariogenic effect of Silver nanoparticles for dental applications, Int J Nano Dimens, 8(4), 361–364.

[38] Danelon M, Pessan JP, Neto FNS, de Camargo ER, Delbem ACB, 2015. Effect of toothpaste with nano-sized trimetaphosphate on dental caries: In situ study, J Dent, 43(7), 806–813.

[39] Maholtra VM, Mehta PK, 1996.Pozzolanic and Cementitious Materials, Taylor & Francis.

[40] Aïtcin PC, 2000. Cements of yesterday and today: concrete of tomorrow, Cem.Concr. Res, 30 (9), 1349–1359.

[41] Hui L, 2004. Microstructure of cement mortar with nano-particles, Compos. Part B: Eng, 35 (2), 185–189.

[42] Chong PBK, 2006. Nanotechnology and concrete: research opportunities, Proceedings of ACI Session on Nanotechnology of Concrete: Recent Developments and Future Perspectives, Denver, USA.

[43] RJM,Lequeux N, van Damme H, 2008. Engineering the bonding scheme in C–S–H: the iono-covalent framework, Cem.Concr. Res,38 (2), 159–174.

[44] Remzi Sahin MO, 2008. New materials for concrete technology: nano powders, 33rd Conference on Our World in Concrete & Structures, Singapore.

[45] Hou P, 2015. Effects of the pozzolanic reactivity of nano SiO_2 on cement-based materials, Cem.Concr. Compos, 55, 250–258.

[46] Zhao S, Sun W, 2014. Nano-mechanical behavior of a green ultra-high performance concrete, Constr. Build. Mater, 63, 150–160.

[47] Bjorn Birgisson AKM, Georgene Geary, Mohammad Khan, Konstantin Sobolev, 2012. Nanotechnology in Concrete Materials, Transportation Research Circular E-C170, 097-8515.

[48] ArefSadeghi Nik AB, 2012. Nano-particles in concrete and cement mixtures, Appl. Mech. Mater, 110–116, 3853–3855.

[49] Yu R, Spiesz P, BrouwersHJH, 2014. Effect of nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete (UHPC) with a low binder amount, Constr. Build.Mater, 65,140–150.

[50] Adak D, Sarkar M, Mandal S, 2014. Effect of nano-silica on strength and durability of fly ash based geopolymer mortar, Constr. Build. Mater, 70, 453–459.

[51] Massa MA, 2014. Synthesis of new antibacterial composite coating for titanium based on highly ordered nanoporous silica and silver nanoparticles, Mater. Sci. Eng. C, 45,146–153.

[52] MorsyMS, AlsayedSH, Aqel M, 2011. Hybrid effect of carbon nanotube and nanoclay on physico-mechanical properties of cement mortar, Constr. Build. Mater, 25 (1),145–149.

[53] Navarro-Blasco I, 2014. Assessment of the interaction of polycarboxylate supe rplasticizers in hydrated lime pastes modified with nanosilica or metakaolin as pozzolanic reactives, Constr. Build. Mater, 73, 1–12.

[54] Fletcher A, Davis J, 2010. How EOR can be transformed by Nanotechnology, SPE Improved Oil Recovery Symposium, Tulsa.

[55] Ayatollahi S, Zerafat MM, 2012. Nanotechnology Assisted EOR Techniques: New Solutions to Old Challenges, PE International Oilfield Nanotechnology Conference and Exhibition, Noordwijk, 12–14.

[56] Wachter WA, Mc Carthy SJ, Beck JS, Stern DL, 2009. Exxonmobil Research And Engineering Company, in vs, US 7504021.

[57] Salinas BJ, XuZY, AgrawalG, RichardB, 2012. Controlled Electrolytic Metallics - An Interventionless Nanostructured Platform, SPE International Oil field Nanotechnology Conference and Exhibition, Noordwijk.

[58] Sharma MM, Zhang R, Chenevert ME, Ji L, Guo Q,Friedheim J, 2012. A New Family of

Nanoparticle Based Drilling Fluids, SPE Annual Technical Conference and Exhibition, San Antonio.

[59] Riley M, Young S, Stamatakis E, Guo Q, Ji L, De Stefano G, Price K, Friedheim J, 2012. Wellbore Stability in Unconventional Shales - The Design of a Nano-Particle Fluid, SPE Oil and Gas India Conference and Exhibition, Mumbai.

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